



Diminishing reliability of standards on environmental noise

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ABSTRACT

Revisions to British Standards in 2014 introduced significant changes in guidance on noise with complex and unexplained limitations. This results in multiple interpretations, assessment methodologies and outcomes depending on the approach applied. Community noise is generally divided into sources of environmental (transport), neighbour and neighbourhood noise (typically arising from commercial sites). The boundaries between different sources is increasingly blurred in the UK with practitioners arguing guidance for one is directly transferable to others. Confusion and ambiguity regarding the interpretation of standards appears beneficial to developers and noise producers who may emit excess noise and those wishing to develop land in noisy areas of the UK that might otherwise be refused permission. An inherent inability to enforce noise controls arises as any interpretation of compliance with standards is duty bound to apply the least onerous interpretation as it is subject to a criminal standard of proof. This problem is compounded with interpretation of controls by UK courts permitting contradictory outcomes and different meanings. Widespread ambiguity, uncertainty and contradictory interpretations now introduced are demonstrated using practical examples. Nullification of existing controls protecting communities in the UK and future guideline principles are explored.

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1. INTRODUCTION

This paper provides the first in a series of investigations into the apparent demise in quality and reliability of some British Standards as assessment tools for environmental noise impact. This paper focuses on BS4142: 2014 Methods for rating and assessing industrial and commercial sound a standard for industrial/commercial sound/noise as a neighbourhood noise source (1).

Anecdotal evidence indicates BS4142: 2014 and BS8233: 2014 Guidance for sound insulation and noise control in and around buildings are unreliable as they provide starkly different results for the same dataset leading to different decisions on noise acceptability. This depends on how the data is presented when each presentation is arguably compliant with the standards (2). Subsequent papers are proposed to examine these outcomes based on empirical evidence. Focus is also on interpretation applied by acousticians in the UK and whether there is inconsistency in the application of the methods of analysis identified. It is questioned whether a change from an independent, uninfluenced approach arises allowing bias aiding development. If so does this potential compromise the objectives and weight to be applied to this assessment mechanism? Separate study of this element is underway. It requires careful analysis as such perception is unhelpful and may undermine the wider opinion of the British Standards Institute on environmental noise.

This paper focuses on some of the anomalies apparent from reading BS4142: 2014 and from its interpretation. Analysis of statements made within BS4142: 2014 indicate the consequences of its application may not have been adequately explored which then undermines confidence in its advice.

The UK Government's Department for Environment, Food and Rural Affairs (DEFRA, UK) Noise Policy Statement for England (NPSE) recognises 'noise' as falling into three categories:

- "environmental noise" which includes noise from transportation sources
- "neighbour noise" which includes noise from inside and outside people's homes; and
- "neighbourhood noise" includes noise arising from within the community such as industrial and entertainment premises, trade and business premises, construction sites and noise in the street" (3)

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BS4142: 2014 addresses the rating of widespread sources of commercial noise. Formerly it was limited to specific responses and a limited range of localities where industrial noise was an expected and integral part of the community. The revised scope of the 2014 version is broad and no longer reflects the original research and experience upon which it was developed. The changes arise with a lack of supporting research.

2. COMPARISON WITH FORMER BS4142: 1997 METHODOLOGY

BS4142: 1997 was headed “Method for rating industrial noise affecting mixed residential and industrial areas” (4). The original concepts on which BS4142 evolved were based on research in the 1950s by Stevens, Rosenbith and Bolt (5). This developed further in the UK by the Building Research Station with a method reported in an appendix in the Wilson Committee report in 1963 (6). The Wilson report established key principles and advice for future development of noise control in the UK which continue to influence today. The first BS4142 was published in 1967, before the widespread use of equivalent continuous sound levels, LAeq (7). It relied on visual averaging of noise levels which were compared to presumed background levels. Many of the 1997 key principles were already established in other standards and guidance such as ISO1996 and from other research including Kosten and Van Os (8,9). In 1990, BS4142 was aligned with ISO1996 and adopted the LAeq index allowing a comparison with the background noise using the LA90 index.

The established principle was of comparing intrusive sources of noise against sounds found in the environment that serve to mask the noise, including the application of a penalty to adjust for acoustic features. The standard recognises it is an objective procedure attempting to assist analysis of a subjectively rated problem.

The development of the standard was primarily based on experience but prior to the publication of the 1997 version, research by the National Physical Laboratory (NPL) provided guidance on the efficacy and problems regarding the practical application of the standard (10). By 1997 it could rely on 30 years experience in operation and supporting research on its application.

Its advice was limited to industrial noise sources in an area where industry and residents co-existed and was directed at the protection of residents against what was judged unacceptable impact. Whilst the focus of BS4142 was to assess impact by measuring noise externally, it was designed to reflect impact on people within buildings as well as gardens.

The 1997 version of BS4142 was based on one hour during the day and 5 minutes at night. There was also the application of a 5 decibel penalty for any recognised special characteristic that increased intrusiveness i.e. a feature that would attract attention. This method persisted until 2014 and effectively, by that time, benefited from 47 years experience as well as research into its efficacy (10). Evolving practice had led to a reasonably consistent approach by most but the standard could have benefited from guidance on its use. The 1995 NPL study found:

1. In over 80% of cases (including those where the standard was used outside of its scope) complaint prediction agreed with incidence. The likely agreement exceeded 90% for assessment within the standard’s scope.
2. In 10% of cases the standard potentially under-predicted complaints. Under-prediction was due to issues including impulse content, low frequency noise (LFN), intermittency and lack of relationship to internal effects.
3. In 8% of cases the standard potentially over-predicted complaints. This was mainly due to the 5dB penalty for tonality being too severe and the existence of screening noise or screening effects in practice.
4. The majority of indoor noise problems related to night time. The correction between daytime of 1 hour and night time of 5 minutes equated approximately to a 10dB adjustment / penalty. This corresponds with wider current practice when comparing day and night impact.
5. LFN was underrated.
6. The evidence indicated the need for cumulative decibel penalties including in the case of intermittency.
7. Reliance on subjective assessment of tonality was a significant reason for errors.
8. There was insufficient account of noise quality. Lack of objective assessment of noise character was recognised as leading to inconsistencies.
9. Operating outside of the scope of the standard reduced prediction accuracy but it still remained in excess of 80% (10)

Having regard to historical findings, changes now introduced in 2014 can be inferred as likely to:

- a. Increase prediction errors due to the widened scope and significant changes to assessment criteria, especially where expectation of commercial and industrial sound is not significant.
- b. Exclusion of LFN should be expected to substantially increase under-prediction of adverse effects in many cases.
- c. Limiting the intermittency penalty to 3dB and apparently excluding its application when other penalties are applied will increase under-prediction. It is not entirely clear whether penalties can be applied cumulatively to include intermittency and this is a further anomaly.
- d. Reducing the adjustment at night approximating which originally approximated to a 10dB penalty for recurrent short term noise to a value now of only 6dB is expected to lead to substantial under-prediction of effects in certain cases and without any rational basis.
- e. Retaining subjective assessment of tonal and impulse content but adding objective empirical assessment procedures will lead to conflicts in use. Application of the objective empirical procedures becomes imperative and this undermines reliability where it is not applied.
- f. Lack of recognition or guidance in the standard of the need to assess internal effects in certain cases where external measurements cannot address source character changes when going inside. This includes tonal effects, differential reduction between source and masking sound levels and low frequency noise content.

It is concluded the changes now introduced, compared to the research findings, indicate significantly increased under-prediction of impact.

2.1 Necessity to develop internal impact assessment methodology

One lacuna recognised in the former BS4142: 1997 and NPL research was its inability to assess differences between internal and external impact. The NPL study recognised the potential to understate impact assessment internally. It is considered the BS4142 standard needs to recognise this risk and identify the need to evaluate internal impact in certain cases and where external assessment can understate internal effects, including tonal and low frequency noise. There is argument assessment should relate to internal levels as the only realistic way of determining actual impact within homes. Added advantages include the ability to undertake measurements during wider meteorological conditions, eliminating uncertainty over the actual differences between source and masking noise experienced internally and reflecting the true circumstances of an internal living environment. Assessment could be based either on actual dwellings, through use of a facsimile enclosure or one that replicates the internal environment. At MAS Environmental Ltd (MAS) we routinely undertake combined internal and external measurements to identify and overcome the errors external measurements can provide.

A range of points were never defined in the 1997 BS4142 standard such as what is considered night time, how many hours a day, week, month or year must intrusion arise for its criteria to apply, what percentage of any assessment period must the special characteristics arise to attract the decibel penalty and what time period should be applied to the background noise LA90 index. The majority of these critical issues remain unanswered in the 2014 version which is compounded by a number of contradictory changes to the method of assessment without empirical evidence, research or experience based support. At the same time of the changes in the 2014 version, the standard introduced substantial and fundamental differences in the method of assessing acceptability and its scope. Not only do these result in unknown outcomes and the risks identified above but different methods of assessment are introduced each which present potentially significant differences in outcome.

It is suggested that introducing unquantified variables in the 2014 version and a specific need to assess uncertainty, whilst at the same time reducing the range over which acceptability is judged to 10dB from 20dB, the standard has become unworkable and at significant risk of understating impact.

The 2014 standard appears to allow practitioners an increased range of circumstances where they can, more or less, choose the outcome of the analysis by selecting the methods that suit their wanted results. This is facilitated by the clause “depending on the context”, which provides practitioners with additional means through which the preferred outcome can be debated. Whilst it is expected ethical standards would prevent misuse, a standard which permits different outcomes for

the same dataset cannot properly be argued as misused or unethical when data is properly manipulated for the desired outcome.

2.2 Flexibility in the 1997 version of BS4142

In the 1997 version of BS4142 the undefined variables were addressed through the application of a wide range on which to judge acceptability which extended 20-25dBA (Source noise LAeq + penalty (if applicable) minus background noise LA90 value giving the complaint prediction level). Unacceptability was positively identified at a rating of +10dBA and acceptability positively identified at a rating of minus 10dBA. Where the 5dB penalty was included it then gave a range of up to 25dBA. Thus whilst an assessor might determine a rating of +5dBA and consider that acceptable, a decision maker could apply a stricter criterion based on the circumstances of the case and method of assessment. This variability gave the standard its flexibility and means to address variations in context or assessment approach. Historically many UK local authorities applied acceptability criteria ranging typically from minus 10dB where increases in noise were to be avoided or the noise character rendered it highly intrusive through to +5dBA for more benign and acceptable sources of noise or where the duration and frequency of impact was reduced. This comparable range of baseline levels is lost as is the built experience when implementing the 2014 version which applies differing criteria and assessment methods. The range of acceptability has been significantly reduced in the 2014 version of the standard. The 2014 version ranges from 0dB to 10dB indicating significant adverse impact depending on the context. Some of the wider differences are considered in more detail here.

3. EMERGING RESEARCH ON NOISE CHARACTER

It is noted historical research by Zwicker and Hellman recognized the inability of the LAeq,T to adequately represent annoyance when measuring decibel levels relating to noise complaints. Their research highlights that measured dB(A) values may not satisfy annoyed people because the recorded energy may not match human hearing. It found that quite often the annoyed people were right and dB(A) value was wrong (11).

A recent study for Health Canada by Michaud et al, in relation to wind farm noise (WFN) annoyance concluded substantial variations in tolerance when comparing against response to transportation noise sources (12). This strongly indicates the need for re-analysis of the use of LAeqT for environmental noise and it is unrealistic to consider WFN unique. The Health Canada study demonstrated on average communities are about 11dB, 16dB and 26dB less tolerant of wind turbine noise than of aircraft, road traffic and rail noise (without vibrations), respectively. The indication is that in relative terms noisiness or annoyance due to different environmental sources of transportation noise vary far more than shown by simply comparing those transport sources with each other. Furthermore the extent of reduced tolerance for a neighbourhood noise was much greater than predicted when looking at the character of WFN and common penalties adopted for those characteristics. Additional study is required to consider the mechanisms leading to such varied human response and their range.

The UK courts have long recognised in a number of judgements that noise character can significantly change acceptability to the point the source can be effectively immeasurable and still cause unacceptable intrusion, where it is “incongruous” and “out of character” in the area in which it occurs. (see *Godfrey v Conwy CBC* 2001, *Roper v Tussauds* 2005 and *Bontoft and Others v East Lindsey DC* 2009) (13,14,15). The importance of noise characterization has also been recognised historically in various guidance including Noise Rating Curves such as the Community Reaction Criteria for External Noises by Kosten and Van Os that was developed to rate noise character internally and within ISO1996.

3.1 Comparison with the approach of the WHO to noise guidance

It is instructive that in their Community Noise Guidelines 1999 the WHO restrict their guideline values primarily to environmental noise sources namely transport noise sources rather than neighbour and neighbourhood noise (16). The differences in noise sources are discussed in detail in the 1995 WHO document Community Noise on which the 1999 Guidelines are formulated (17). The WHO focus on “critical health effects” of noise and thus in any event do not reflect acceptability

of a community to a source of noise. The WHO guidelines contain a range of clear caveats indicating the limited scope of their guideline values and in so doing reflect the difficulty in setting criteria for neighbourhood noise when it includes a range of special characteristics. One main purpose of policy at EU and WHO level is to reduce and manage noise from the greatest noise polluting sources predominantly road traffic noise, aircraft noise and rail noise. Sources such as industrial noise, are sources of neighbourhood noise, but do not affect the same percentage of the population. However, such sources can give rise to high levels of annoyance locally. Notwithstanding advice from the WHO over its guidelines there is widespread evidence of misapplication of the guidelines within the UK as evidenced in numerous cases determined by the courts.

The WHO state: *“While sound can be measured with the help of acoustical instruments such as sound level meters the actual extent of noise nuisance cannot be measured in this way. ... Large-scale population studies show that only one third of noise annoyance can be accounted for through exposure to varying sound levels. Non-acoustical factors, including personal factors such as noise sensitivity, and social factors can have as much effect as the sound level.”* (18)

This advice from the WHO is logical as we have significant research for general environmental noise that is not site or character specific but that relating to industrial and other commercial sources of neighbourhood noise is limited. Emerging guidance identifies the appropriateness of this WHO advice as evidenced in the Canadian (Michaud et al) study already referenced where wind turbine noise is determined as likely 11dB, 16db and up to 26dB less tolerable than aircraft, road traffic and railway noise respectively (12). Despite this clear guidance it is common in the UK for many consultants to argue the WHO guideline values are transferable to any specific source of community noise. A future paper in this series is directed at the investigation of the erroneous adoption of such guideline values for noise with character i.e. arising from a specific site and recognisable by humans in dwellings.

4.0 UNQUANTIFIED AND UNQUALIFIED CHANGES TO BS4142 IN 2014

The changes to methodology which lead to widespread uncertainty are broad such that it is impossible to rely on the historical experience or research using the former standard. The full extent are not addressed in this paper and focus here is directed at outlining some changes which likely undermine the reliability of the standard. Examples based on empirical analysis are to follow in future papers.

Fundamental changes and anomalies are considered to have been introduced without explanation, guidance, empirical or evidential support. Impact from noise commonly results from the cumulative sources which combine and may be exacerbated by factors such as other pollution including light, odour and vibration. The cumulative impact cannot be assessed not just because there is no reference to exacerbating factors but because many such features are deliberately excluded. Some significant changes and anomalies include:

1. **Change in scope.** Extending the standard to all areas and localities of the country whether tranquil, remote rural or intense urban / commercial locations. The standard is no longer restricted to mixed industrial and residential areas where there is already an expectation of noise impact leading to greater tolerability. It now includes all areas. Co-existing with industrial noise where it is an integral feature must be expected to produce greater tolerance compared to a locality previously absent industrial or commercial sources. This unknown variable has not been factored into the advice on rating in the 2014 version and permitting this change is without supporting research. Further the rating range now provided in the standard appears too small to reflect the differences. In effect tranquil areas free of machine generated noise could no longer resist incongruous alien sounds being introduced. Under the previous standard virtual inaudibility was arguable where it was warranted, despite its already industrial context. This would not be achievable in the 2014 version producing a relaxation of controls that is not overtly apparent. It would, for example, also apply to work at home by a mechanic repairing cars in a wholly residential area not expecting such noise but excludes the people and radio noise.
2. **Ambiguity on vehicle noise.** There is inclusion of commercial vehicle noise on a site but it is

unclear if the 2014 version of BS4142 excludes customer vehicle noise. In a recent planning inquiry it was argued customer noise was excluded despite it constituting the majority of the noise impact (18a).

3. **External assessment.** The standard states at one point it uses outdoor sound levels to assess, amongst other things, likely effects of sound on people in buildings but later that it is not applicable to the assessment of indoor sound levels. Whilst there are subtle differences in wording the message is mixed. There is no reference to the risk of understating impact internally that is recognised in research.

4.1 Specific Exclusions and the anomalies introduced

The standard appears to extend to all commercial noise sources (save where other guidance exists or source is specifically excluded) regardless of the differing non-acoustical and acoustical effects.

- i. There is exclusion of sound from recreational activities, entertainment music and motor sport regardless of any similarity to some other sources of commercial noise. Recreation is commonly defined as something done for pleasure whilst not working.
- ii. It is unclear if plant noise from commercial premises providing recreation, such as restaurants, cinemas, sports halls and public houses is excluded.
- iii. Vehicle testing grounds which test motor sport and road vehicles or provide filming of vehicles are included but motor sport as an entertainment for the public is excluded regardless of similarity in noise character.
- iv. A loud radio used for entertainment, public address or voices at a factory at night are excluded but other noise from commercial activity at such a site is included.
- v. Shooting grounds are excluded regardless of noise source, including their plant noise. This includes inside grounds. Conversely firework, gun cartridge and other explosives testing are included.
- vi. Domestic animals are excluded which is presumed to extend to animal boarding establishments but commercial animal noise on farms is included. Sound from people is excluded.

4.2 Effect of other guidance / standards

The 2014 standard states it “is not intended to be applied to sources falling with the scopes of other standards or guidance.” This is not further differentiated or clarified and has led to conflict in a number of decision making processes at major public inquiries and within court cases. Such exclusion is viewed unsound.

If BS4142 is soundly based and a reliable assessment tool for most commercial noise and it applies a reasonable method of assessing acceptability, it is a matter of logic that it should not be excluded by the introduction of other guidance. That other guidance would normally be compared and contrasted with BS4142 as an existing procedure and applicability would depend on the reliability of BS4142 as a prediction tool compared to any alternative guidance. Conversely the implication is that BS4142 likely fails to reflect the necessary control of various commercial noise sources for an unknown range of sources and should be abandoned as soon as other specific guidance is provided. In particular there is no restriction on the purpose of the other guidance or its reliability. Regardless, this leads to exclusion of BS4142. The standard is not applied where other guidance is available and whether applicable to the circumstances of assessment, produced by the industry to protect its interests, independently developed or based on government policy.

The wording implies that if other standards or guidance is available which relate to a source, then regardless of the circumstances, BS4142 does not apply. In its widest sense the WHO Community Noise Guidelines 1999 as amended by the WHO Night Noise Guidelines 2009 apply to all forms of commercial noise. They do not set acceptability criteria in most cases but permit an argument they do provide guidance in specific scenarios. In turn this presents an argument BS4142 is universally not applied. This cannot have been the intent of the exclusion and is illogical. There are, in any event a range of guidance documents which could be considered applicable and nothing prevents an industry introducing their own guidance affording disproportionate benefit but supporting an argument BS4142 is not applicable. Two specific and common anomalous situations in the UK already exist and are discussed below.

4.3 Minerals planning guidance

Guidance is provided by UK Government on the acceptability of minerals site related noise in

relation to their extraction. It is recognized this guidance is weighted to reflect the need for minerals. This is a policy related document which is not independent or uninfluenced as would be expected of a British Standard. The guidance is argued as developed for national policy requirements and is limited to permitting new development. It does not provide a method for the investigation of complaints of noise intrusion. The UK Supreme Court has determined that planning criteria is effectively unrelated to the assessment of nuisance and whilst the determination of nuisance is beyond the scope of BS4142 it nevertheless has long been accepted by the UK courts as providing objective evidence to assist a court determine nuisance (19). Such use is discussed in the 1995 NPL research.

Avoidable ambiguity arises. It remains unclear whether in the case of minerals works, guidance in BS4142 can apply due to the differing objectives or, alternatively is now void. In any event such differentiation causes contradiction and undermines both forms of assessment which is then complex for any decision maker to conclude upon. It is to be recognised that misapplication of guidance could enable a decision to be challenged. On a strict reading of the wording BS4142 it arguably does not now apply to minerals works as it is a source of noise falling within the scope of government guidance designed to further their policies on noise. Conversely that outcome is contrary to one of the main objectives of the British Standards Institute.

4.4 Wind Farm Noise Guidance in the UK – ETSU-R-97

The UK Government has persisted in applying ETSU-R-97 for the assessment of wind farm noise for a period approaching 20 years (20). Regardless of the support or criticism of this guidance it is in effect directed at the assessment of the development of wind farms and does not relate either to the assessment at residential property already impacted by wind farms, any nuisance caused by wind farms, the re-rating of property values affected by WFN and complaints unrelated to planning compliance such as for statutory nuisance. Guidance prepared by Defra on the investigation of nuisance from wind farms confirms the inapplicability of ETSU-R-97 to nuisance assessment which is also indicated in the document itself (21).

As with minerals cases, it remains unclear whether BS4142 is not applied to wind farms because of other guidance or merely not applied when considering their development. Most practitioners argue it is not applied *per se*. There is no sound reasoning for this.

4.5 Low frequency noise (LFN)

Different language is used in the standard in relation to low frequency noise where it states “The standard is not applicable to the assessment of low frequency noise”. Readers are directed to considering guidance produced by the University of Salford but this is not directly transferable to cases of commercial noise, not least as different definitions of LFN arise (22). The alternative guidance looks at a narrow range of circumstances and LFN up to 160Hz. It is generally accepted in the UK that LFN extends to 250Hz and in some references is considered to extend to higher frequencies (17). This is also contradicted by Annex C of BS4142 which references anything in the third octave bands up to 125Hz as low frequency. Thus there is a lack of consistency that should have been identified by its authors. This problem reflects concern over the depth of analysis when implementing the radical changes in this guidance, introduced absent experience or research of the outcome.

Widespread commercial noise sources include LFN as a proportion of their content and it is rarely a case of LFN in isolation. The inference in the 2014 version of BS4142 is that the LFN portion would be excluded from the assessment and cumulative effects are therefore ignored. This increases uncertainty and undermines enforcement as it creates a readily recognised lacuna in the guidance from 125-250Hz. Where there is LFN content but the source is not wholly dominated by LFN reliability is lost. It is difficult to conceive how this issue was left unaddressed which further undermines confidence in the wider advice provided in the new standard. It would have been simple to recognize the increased intrusiveness of LFN as recognized in the WHO guidance.

Assessment problems are compounded and the standard is unhelpful on how to assess situations which contain some LFN. In many scenarios there is almost universally significant LFN content.

4.6 Field calibration checks – conflict of standards

BS4142: 2014 introduces checks on calibration at the start and end of a measurement session regardless of the length of the period of measurement. In many cases measurements could extend several months, especially when establishing typical background noise levels. In contrast BS4142: 2014 relies on ISO1996 2007 which requires daily calibration checks.

4.7 Wind direction

It is long recognised that over distance, comparing upwind and downwind propagation of sound leads to significant differences in level. This difference is typically considered of the order of 12dBA at distances of about 600m with downwind levels higher (2). Furthermore downwind propagation is recognised as more stable than cross wind and upwind. It is considered high wind shear effects (significantly increasing sound speed gradient with height) can enhance these differences, especially at night. The 1997 version of BS4142 was aligned with BS7445: 2003 which replicates ISO1996 and in turn seeks measurements are made downwind or adjusted for downwind conditions. This provides certainty and consistency in comparison. Propagation conditions such as found in ISO9613-2 predicts downwind sound levels (23). Thus it was reasonably concluded that the criteria in BS4142: 1997 was based on downwind levels.

BS4142: 2014 no longer relates its guidance to BS7445: 2003 and only addresses wind direction as an uncertainty factor suggesting best practice is to measure downwind. This change in emphasis is significant as it permits assessment under any wind direction and there is no requirement to adjust results for downwind where there is typically the largest propagation of sound. In other words selection of conditions can dramatically change the results but would now remain consistent with BS4142: 2014 save the need to identify it as a potential uncertainty. Under low atmospheric wind speed gradients upward refraction of sound can lead to significant sound shadow not found under other conditions. This undermines reliability and comparability. Whilst it is to be recognised measurements cannot be restricted to best propagation conditions in practice, adjustment to provide consistency when assessing impact against a fixed criteria is viewed essential for any procedure that is based on short term measurements such as provided for in BS4142.

4.8 Measurement Location

The standard references that measurements are to be made at the “assessment location” but then fails to describe or define what fits such a description. Whilst arguably this can be assumed to relate to the worst affected façade, it is by no means clear.

The 1997 version of BS4142 sought either to use a ground floor level free field measurement at least 3.5 metres from buildings or in the case of higher floors, a level 1m from a relevant building façade. It is commonsense and addressed in ISO1996 that when assessing noise impacting persons in buildings measurements are generally undertaken 1-2m from a façade. This is logical and in agreement with the BS4142: 1997. Provided background noise and source noise are measured at the same location, they are comparable. When considering noise incident on a building façade it is argued illogical to measure away from that façade as it is liable to corruption from sources of noise which are not incident on the façade. This logic is embodied in the advice in BS7445 and the 1997 version of BS4142 but changed in the 2014 version where the objective is always to measure at least 3.5m away. The consequence is elevated background noise compared to that incident on a façade due to the unobstructed degree of the microphone over which noise will be received compared to the building facade. This increases the background noise level and thereby permits more noise.

There is no logic or reason in science for adopting a method that less reflects noise incident upon or within an affected building and it likely results in unrealistically elevated background noise. Research by MAS has demonstrated that in the absence of a main directional background sound source such as a busy road, decibel levels generally elevate 3-4dB when moving away from a building, from 3.5 to 10 metres distant (24). Figure 1 below demonstrates one reason why this is unrepresentative.

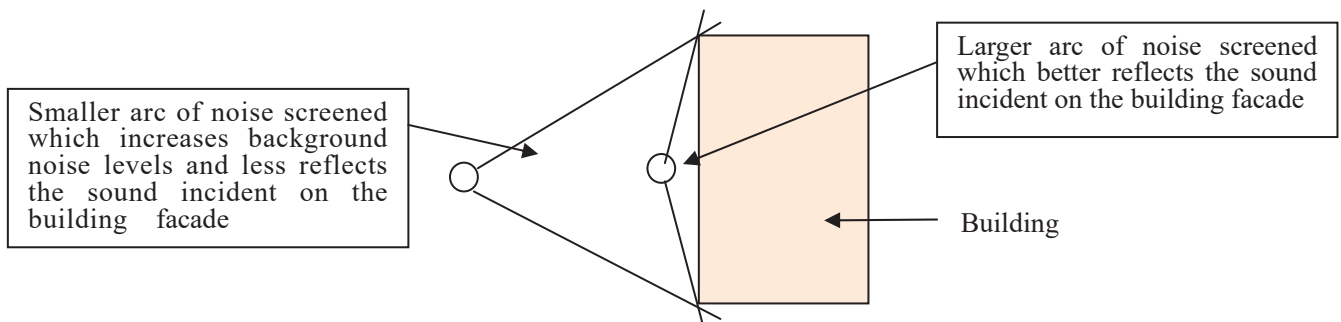


Figure 1 – Shows reduced screening of extraneous noise further away from building

4.9 Anemometry measurements

The standard seeks the measurement of meteorological conditions whilst sound monitoring progresses but does not set a height for those measurements or address their significance, such as wind direction. The former 1997 version was aligned with BS7445:2003 which addressed the conditions under which to measure noise but this is not repeated in the 2014 version creating additional anomaly (25).

4.10 Uncertainty in assessment

The 2014 version of BS4142 introduces the need to evaluate some elements of uncertainty. This was implicit in the 1997 version and addressed through the range of acceptability criteria which extended from minus 10dB to plus 10dB. Guidance is given on measurement, instrument and calculation uncertainty in the 2014 version but ignores the fundamental issue of frequency and duration uncertainty in relation to the source of intrusion. Further the percentage of time any special characteristics contained within the noise arise is not considered. These issues have always presented the greatest difficulty in determining the rating and assessment of noise and create much uncertainty but are not discussed in BS4142: 2014.

No differentiation is made whether a special characteristic occurs continuously throughout the 16 hour day or occurs for a brief period during any one hour. Similarly it does not differentiate if impact is every day or occasionally, whether it occurs at times when greater freedom from noise is expected such as evenings and weekends, is unstopping or brief. All scenarios appear rated the same.

Additional uncertainty is introduced as the 2014 version allows character correction assessment using one of three different approaches. One is a subjective judgement and two require empirical assessment. The 1995 NPL research identified problems with some elements of subjective assessment. It is unclear what is to happen when these methods give conflicting results. It can only be that empirical based methods take precedent as that excludes human bias and is repeatable. This renders use of subjective approaches unsafe.

Decibel penalties for impulse noise and tonality, up to 9dB and 6dB are cumulative but that for other character appears neither cumulative nor reflective of increased intrusiveness at only 3dB. It is possible to interpret the 2014 version in different ways over the application of penalties. As identified the Canadian Health study found human tolerance of WFN varies from 11-26dB less than for different transport sources. However, WFN rarely contains significant tonality or impulse content. This large differential appears to arise due to the incongruity within the noise and in particular its erratic modulation and changing spectra moment to moment. This places the noisiness of other character as potentially greater than tonal and impulse character, along with non-acoustic factors. This is not recognised in BS4142: 2014.

4.11 Changing the period of assessment at night from 5 minutes to 15 minutes.

Averaging over 15 minutes rather than 5 represents a fundamental change from 1997. The 5 minute period used was long established and the change is without any identified basis in science. It significantly alters the limits of acceptability and equates to permitting an increase of intrusive noise of the order of 5dB. Where is the evidence to show the former BS4142, which is based on many decades of experience and application, was overly restrictive on night time noise?

The former method meant that where a noise was continuous through the night its procedure was the same as when assessing 15 minutes or an hour. However, short term noise impact at night such as an activity occurring over 30 seconds that was loud enough and liable to awaken people (as advised in the guidance of the WHO 2009) would previously only be averaged over 5 minutes but is now averaged over 15 minutes (26). Thus a 30 second noise occurring perhaps 15 times through the night without special characteristics and causing external levels of say 63dB $L_{Aeq(30\text{ second})}$ causing awakenings due to internal levels when windows are open of 48-53dBA, in an otherwise quiet area (background noise level of 42dB L_{A90}) would give an acceptability rating of 11dB (53dB $L_{Aeq(5\text{ minutes})} - 42\text{dB } L_{A90} = 11\text{dB}$). This is clearly judged unacceptable when applying the procedures in the 1997 version especially when considering frequency of occurrence. The new procedure gives a rating of 6dB (48dB $L_{Aeq(15\text{ minutes})} - 42\text{dB } L_{A90} = 6\text{dB}$). This is readily argued as acceptable.

The original selection of night-time averaging over one twelfth of the daytime hour was clearly deliberate to reflect the increased sensitivity at night due to sleep disturbance and the relevance of short duration impact. This jump in the 2014 version permitting higher night time intrusion has been introduced without any evidential support and patently now permits sleep disturbing events that were formerly considered unacceptable. Again this change arises with no apparent regard to the

collective experience and demonstrates an apparent bias in favour of polluters, disregarding the need of residents.

4.12 Application of ISO1996: 2007 and assessment of tonality

This standard has not been adopted in the UK and reliance continues to be placed on the former versions which are reproduced word for word in BS7445: 2003 and BS7445: 1987. BS4142: 2014 relies on ISO1996: 2007. This standard applies a different approach to tonality assessment than that formerly accepted in the UK in the extant BS7445 which defines environmental noise measurements. It therefore creates direct conflict between extant British Standards.

The extant BS7445 was useful for determining the meaning of tonality as applied in the 1997 version of BS4142, especially as the latter included references to drones and hums as well which commonly relate to LFN content. Thus there is conflict in that BS4142: 2014 references a standard not adopted in the UK and ignores the adopted BS7445. There is also conflict as the same language (hums and drones) is used as in the former version but with a different meaning. BS4142: 2014 also permits the determination of tones using the Joint Nordic Method 2, increasing ambiguity. This arises as part exclusion of LFN in the assessment procedure means part of the methods referenced need to be discounted. Also the Nordic method uses an averaging time in excess of 1 minute and typically of 2 minutes. This averaging can mean short term tone bursts are ignored. Put another way, the standard is suited to continuous mid and high frequency tones but not otherwise.

BS4142: 2014 permits the application of a penalty up to 6dB for tones, drones and hums on a subjective basis. Where multiple varying tones occur when the spectrum content rapidly changes over time it can be subjectively and objectively assessed as containing special character warranting a penalty but if evaluated using ISO1996 2007 by either objective method including the Joint Nordic Method 2 it can fail to recognise the tonal content as intrusive and lead to their exclusion. This introduces further uncertainty and ambiguity. The fallback in any assessment is identified as the Joint Nordic 2 method. Commonly hums are low frequency and listening to a source of noise without empirical assessment typically produces a judgement applying a significant penalty. As BS4142: 2014 excludes assessment of low frequency content and thus excludes consideration of any low frequency hum or drone it contradicts its own approach and methods adopted. The objective procedures on tonal assessment adopted and reproduced do not recognise the standard's exclusion of low frequency noise assessment. Thus the empirical standards in ISO1996: 2007 applies a different scale to rating lower frequency tones but this is not applied by the exclusion in the standard when relating to LFN. The third method, the Joint Nordic 2 Method is subject to longer term averaging that is unlikely to reflect the impact of short term tone bursts.

In practice any subjective assessment of tones would be superseded by application of the empirical procedures and whilst this has merit, it does not remotely relate to the method of determining special character in the former BS4142 which is based on experience nor does it reflect human response to complex varying tones, especially as low frequency tones are ignored. Ultimately the only way of achieving certainty is through the use of the fallback procedures for dispute, the Joint Nordic 2 method. In effect the standard provides an elaborate hierarchy of tonal assessment which is inadequately defined as to priority but ultimately it can only safely rely on one procedure. Impulse assessment is less complex but nevertheless also includes contradiction.

Thus the standard has gone from subjective assessment of tones, hums or drones as a broad category of characteristics which could be empirically evaluated on a broad basis using BS7445 and which generally recognised them as more intrusive, to assessment of a narrower range of tones using a detailed empirical method which primarily rates longer term average tones. As a result the standard excludes a range of intrusive forms of noise and it builds in uncertainty through applying potentially conflicting methods. In any compliance assessment a standard of "beyond all reasonable doubt" applies and enforcement is duty bound to apply the most lenient process in order to meet the doubt test. As a result any assessment would have to apply all the conflicting methods and judge compliance using the most lenient method. In practice such a complex web of control becomes impractical and leads to a lack of enforcement.

4.13 Inadequate procedure for determining residual sound

The standard is silent on a number of elements, for example the best method for determination of residual and ambient noise levels which are critical and require default processes in the event of uncertainty. BS4142: 1997 provided a process for addressing this which is absent in BS4142: 2014.

4.14 Other inconsistencies

A range of other inconsistencies arise which are not addressed here including advice which conflicts with BS8233: 2014 on façade effects. As both standards were published within a few months of each other, reliability is questioned when both give different advice.

5. CONCLUSIONS

Simple analysis of the revised BS4142 reveals a catalogue of anomalous and erroneous changes which have no apparent basis in science or research and that largely abandon the long established principles derived from decades of experience and research which led to the evolution of guidance found in the 1997 version. *Prima facie* changes benefit developers without any basis for subjecting residents to greater noise disturbance.

BS4142: 2014 is unable to rely on either long experience or specific research to support many of the changes introduced. Emerging evidence on the tolerability of neighbourhood noise containing special characteristics indicates relaxation of control as seen and specifically at night is not sustainable. Further, having regard to the range of neighbourhoods which are now treated the same in BS4142: 2014, regardless of their differences in tolerability, without appropriate empirical consideration of the consequences is baseless and flawed.

The change in evaluating uncertainty which previously was reflected in the selection of the point of acceptability within a wide ranging scale of 20-25dB is now lost. The range is dramatically reduced placing all variables within a small decibel range and thereby treating widely varying intrusive character, expectation and acceptability as virtually warranting the same permitted levels of intrusion.

Changes appear neither science based nor reflecting experience. In most cases they serve to permit more noise.

There has been a failure to address the critical uncertainties such as frequency and duration of source occurrence and also the percentage of time they emit special characteristics with no differentiation in assessment between rarely occurring sources and those that are more or less continuous. Whilst there is scope to consider these differences in context, the assessment range is too narrow to suitably adjust for the differences. As a consequence greater intrusion must be expected.

Conflicts with other standards and within the procedures inherent in BS4142 have not been addressed and exclusions of its application poorly considered.

Analysis of basic elements of noise impact assessment reveal a number of lacunas in the revised standard including relating to low frequency noise exclusion, the penalty for characteristics other than impulse and tonal content, exclusion of application to some sources but inclusion of similar source, exclusion of applicability where other guidance applies and how that is to be interpreted and conflicts over measurement locations. Confidence in effective prediction of impact previously associated with BS4142: 1997 is now undermined with alternative outcomes obtainable using the same dataset achievable. The presence of clear contradictions, anomalies and obvious problems arising from the changes introduced raises doubt whether there was appropriate consideration and testing of the changes. Simple analysis shows changes permit both more and clearly unacceptable noise, as demonstrated by the unexplained change from averaging over 5 minute periods at night to 15 minutes.

Prima facie the standard appears biased towards permitting increased noise impact upon communities. The complexities now introduced render reliance on BS4142: 2014 as a prediction tool unsafe. The discursive analysis undertaken in this paper is to be followed by series of empirical assessments to evaluate the extent of problems and contradictory outcomes indicated.

In view of the abandonment of experience based principles BS4142: 2014 cannot be concluded as a reliable indicator of community acceptability absent empirical based research. Amendments are needed to address the wide ranging anomalies and absence of specific guidance in relation to a range of scenarios and situations such as the inclusion of low frequency noise as a contributor to impact.

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REFERENCES

1. BSi. BS4142 2014 Methods for rating and assessing industrial and commercial sound. BSi: London.
2. BSi. BS8233: 2014. Guidance on sound insulation and noise reduction for buildings. BSi: London.
3. DEFRA. Noise Policy Statement for England. London: DEFRA; 2010. Available at <https://www.gov.uk/government/publications/noise-policy-statement-for-england>
4. BSi. BS4142: 1997 Method for Rating industrial noise affecting mixed residential and industrial areas. BSi: London.
5. Rosenblith WA, Stevens KN and Bolt RH. "A Community's Reaction to Noise: Can it be forecast?" *Noise Control*, 1, 63-71, 1955.
6. Committee on the Problem of Noise. *Noise: Final Report*. London: HMSO;1967.
7. BSi. BS4142:1967 Method of Rating Industrial Noise Affecting Mixed Residential and Industrial Areas. London: BSi (includes 1975 amendments)
8. International Standard, ISO 1996-2:2007 Acoustics -- Description, measurement and assessment of environmental noise -- Part 2: Determination of environmental noise levels
9. Kosten, CW and Van Os, GJ. COMMUNITY REACTION CRITERIA FOR EXTERNAL NOISES. National Physical Laboratory Symposium No.12. HMSO: London; 1962 pp.373-383.
10. Porter N., 1995. National Physical Laboratory - Study of the Application of British Standard BS 4142:1990 "Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas" (The Data Sheet Study). Middlesex: NPL.
11. Hellman R and Zwicker E. Why can a decrease in dB(A) produce and increase in loudness? *J. Acoust. Soc. Am.* 82 (5), November 1987. pp. 1700-1705.
12. Michaud et al. Personal and situational variables associated with wind turbine annoyance. *J. Acoust. Soc. Am.* 139 (3), March 2016. pp. 1455-1466.
13. *Godfrey v Conwy County Borough Council* [2000] CO/438/2000 Available at <https://cases.legal/en/act-uk2-9504.html> [Accessed 22/05/2016]
14. *Roper and another v Tussauds Theme Parks Ltd*, [2007] EWHC 624 (Admin)
15. *Bontoft v East Lindsey DC* [2008] EWHC 2923 (QB)
16. World Health Organization. *Guidelines for community noise*. Geneva: WHO;1999.
17. World Health Organization. *Community noise*. Edited by Birgitta Berglund & Thomas Lindvall. Archives of the Center for Sensory Research, 1995, 2(1), 1 - 195. Stockholm: Sweden.
18. World Health Organisation, 2000. *Noise and Health* (Local authorities, health and environment briefing pamphlet series; 36). Denmark: WHO.
- 18a. Planning Inspectorate APP/N4720/W/15/3009739: The White Bear, Dewsbury Road, WF3 1JX
19. *Coventry v Lawrence* [2014] UKSC 1
20. Energy Technology Support Unit, ETSU-R-97 The assessment & rating of noise from wind farms 1996
21. NANRA277. Wind Farm Noise Statutory Nuisance Complaint Methodology. Report Prepared for Defra: Contract No. NANR 277 - 2011
22. Moorhouse A, Waddington D and Adams M. Procedure of the assessment of low frequency noise complaints. Contract no NANR45. Manchester: University of Salford.
23. International Standard, ISO 9613-2:1996 Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation
24. MAS Environmental Ltd - Comparative study of background noise and wind speed data Brass Castle, Nr Harrogate (Bilberry Farm wind turbine proposal) February 2012
25. BSi London. BS7445: 2003 Description and measurement of environmental noise. Guide to quantities and procedures
26. World Health Organization. *Night Noise Guidelines For Europe*. Denmark: WHO;2009.